Safe nests in global nets:

Why strategic R&D is (still) homebound in wireless telecom[1]

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1. INTRODUCTION

1.1. Background

Globalization is a relevant issue for policymakers and firms alike. Although individuals, firms, and countries have always been connected in various ways throughout history, commentators generally claim that globalization has caused a once-unfathomable new height of connectedness at the dawn of the 21st century. This is typically considered to be the outcome of the combined effects of regulatory, political, and market liberalization combined with technological change, especially in information and communication technologies (ICT). In short, globalization might be defined as *"the high and increasing interdependency and interrelatedness among different and geographically dispersed actors"* (Archibugi and Iammarino, 2002, p. 99; for a popularized discussion see also Friedman (2005)).

The most visible trend of globalization, from the viewpoint of firms, has been foreign direct investment (FDI), in the form of the outsourcing and offshoring of manufacturing. However, the rapid change in the global division of manufacturing has perhaps overshadowed another phenomenon: the internationalization of research and development (R&D) (UNCTAD, 2005). Globalization of R&D means researchers and inventors increasingly tend to be located outside the home country of their companies. Despite this trajectory, Patel and Pravit present the non-globalization argument in a seminal paper (Patel and Pavitt 1991), suggesting that the actual inventive activities of multinational corporations (MNCs) tend to be significantly less globalised than the international distribution of R&D expenditures seems to indicate. Patel and Pavitt (1991) suggest that this may be because country-specific characteristics of national systems of innovation still matter for more strategic R&D activities; they highlight such issues as the importance of physical proximity and tacit knowledge, education, training, and basic research. Indeed, R&D internationalization is still today a much-debated subject. Several studies, which will be reviewed in later sections, have recently documented that a growing share of R&D of MNCs is off shored, but evidence is mixed and the "non-globalization" argument also finds support in other empirical analyses.

My focus on the wireless telecommunications industry is particularly interesting and relevant to this debate for three reasons. *First*, this industry has benefited from trade liberalization, deregulation, and technological change, as governments around the world are developing and upgrading their ICT infrastructures (Zysman and Newman, 2006). *Second*, the industry has also changed its technological core due to the convergence of data- and telecommunications and the emergence of the Internet, thus providing multiple entry points for firms and inventors, including new geographical locations outside the US and Europe. *Third*, much of the extant research on the internationalization of R&D tends to treat R&D as a `black box´ where the specificities of different types of R&D are undisclosed. This is partly a consequence of the lack or inaccessibility of detailed data on the different types of R&D and inventive activity at the firm level. Due to the significance of standardization, a system of notification of patents deemed essential to specific standards has been set up. This system provides an interesting analytical lens for identifying R&D and inventive activities that lie closest to the technological core of the industry in a strategic, and perhaps also commercial, sense. I will argue that entering into the discussion of patents and Intellectual Property (IP) is beneficial to an examination of the internationalization of R&D as it allows a closer look at the ways the management of intangibles can influence the exploitation of international R&D investment.

This paper contributes to research providing a new interpretation for the homeboundedness of critical industrial R&D, and in general to the literature on appropriability and maturation of R&D off shoring. I was able to discuss the result of my quantitative empirical analysis directly with the managers involved in key decisions relating to the development of some of these technologies. Their viewpoint suggests the presence of what I have defined "*Safe R&D nests*". I will discuss that such "safeness" derives by a close coordination between scientific and technological research and management of intangible assets.

1.2. Aim and structure

This paper compares the international distribution of strategic R&D activities related to the development of wireless standards to other (non standard related) projects in the telecommunication industry. While there is evidence that leading companies in this industry are globally sourcing their know-how, more strategic R&D projects still remain homebound.

Conversations with R&D and Intellectual Property (IP) managers at Ericsson, Motorola, Nokia, and Qualcomm further support this finding. These semi-structured interviews confirm the mainstream views that R&D subsidiary maturation and organizational inertia limit the decentralization of strategic innovative activities. Managers claim that the level of appropriability of R&D is not the same throughout the entire company. Some centers and labs have developed better coordination between R&D technicians, lab managers, and IP experts. Such coordination was generally higher at the headquarters of these companies where the central R&D labs were located. Such domestic centers preserved the desirable setting for a high level of exploitation of R&D results, making them unchallenged "Safe Nests" where strategic technologies were nurtured and developed.

The paper is structured in the following manner. In the second section I provide a brief conceptual discussion of major interpretations of R&D internationalization and a review of the major themes in the empirical literature. I also consider the specificities of the wireless telecommunications industry. In the third section I discuss the data I use and provide empirical analysis of essential patents notified to ETSI (European Telecommunications Standards Institute), and less essential ones. In the fourth section I validate my statistical analysis through interviews with managers at the four companies and present the Safe R&D Nests interpretation. I will conclude and identify possible avenues for future research in the fifth and final section.

2. The internationalization of R&D

2.1. Three drivers of R&D internationalization

Given the relatively recent nature of a fairly confined but growing phenomenon,[1] much attention has been given to the causes and consequences of R&D internationalization. This is particularly true as the competitiveness of firms and the development of regions where MNCs are headquartered are at stake. The literature identifies three main drivers for the internationalization of R&D.

The *first* driver of R&D internationalization is adaptation to foreign demand. As MNCs expand their export activities for new or existing markets they need to invest more resources into understanding the nuances of foreign markets in order to adapt their products to the different needs of these clienteles. R&D efforts in this case offer the logistical support to leverage overseas knowledge generated in the central, and generally domestic, R&D lab. The knowledge flows of such investment are therefore one-way only, from the center to the periphery (Dunning, 1958, Hymer, 1976). Scientists and technicians remain homebound and the result of critical R&D activities is combined with know-how of a local market for the local exploitation of a globally homogeneous production. Scholars call this type of investment "adaptive R&D" since it is driven by the desire of MNCs to enter new markets and exploit home-based advantage through foreign activities (Kuemmerle, 1997).

Investing in a firm's "absorptive capacity" is a critical juncture for a *second* driver of R&D internationalization (Cohen and Levinthal, 1990). An R&D presence overseas might be necessary given (1) raising levels of technological integration and specialization, (2) the need to gain access to and exploit pockets of knowledge located in various countries, as well as (3) the need to integrate "peripheral" forms of knowledge with core technologies. Today, companies do not go abroad merely to exploit home-based knowledge for foreign markets, but also to learn and explore foreign knowledge located in deep pockets overseas (see here: Gerybadze and Reger, 1999; Dunning, 1994; Kuemmerle 1997, 1999). As understanding of this type of `home-based augmenting´ R&D is gaining ground, scholars argue that the characteristics of individual firms are relevant to understand their specific location strategies (Alcacer and Chung, 2007).

The *third* driver of internationalization is the access to and use of cheaper factors of production for the more time-intensive phases of an R&D project. This form of internationalization shares characteristics similar to the modularization and decentralization of manufacturing activities. Such a phenomenon is heavily discussed in the organizational literature.[2] Modularization of an R&D project (Brusoni et al., 2001) theoretically renders possible a distribution of labor within a company and the delocalization of time intensive R&D phases to peripheral laboratories localized in areas with access to a cheap and qualified labor pool. [3]

2.2. Maturation of foreign R&D investment

Adapting to local foreign demand, tapping into deep and distant knowledge pockets, and achieving cost reduction by offshoring advanced service functions lead to a rethinking of the entire R&D workflow and, in particular, a reorganization of strategic planning, support functions, and time intensive phases of development projects. This process does not happen overnight and there is a vast amount of literature focused on the trial and error process that guides MNCs through the reorganization of their international technological activities. While it is not possible here to review the large and growing literature, it is worth pointing out three aspects that guide empirical and theoretical discussion: maturation, authnomy, and coordination.[4]

Maturation suggests that as foreign R&D sites increase their local know-how, they are assigned different tasks and responsibilities by the headquarters (Birkinshaw (1996) and Birkinshaw and Hood (1998), Gerybadze and Reger (1999), von Zedwitz and Gassmann (2002), Mendez (2003), Mudambi and Navarra (2004)).[5] *The level of autonomy from the headquarters* sets the conditions for a trade-off between central coordination and local "embeddedness", and exploitation of foreign knowledge pockets (Zander (1997 and 2002), Gerybadze and Reger (1999), Rugman and Verbeke (2001), Frost (2001), Mudambi and Navarra (2004)). *Coordination* between local "centers of excellence" and the headquarters is one of the dimensions of organizational models for an MNC with distributed R&D investment (Birkinshaw and Morrison (1995), Birkinshaw (1996), Asakawa (2001), Frost et al. (2002)).

2.3. Evidence of non globalization: Patel and Pavitt (1991) revised

The seminal paper by Patel and Pavitt (1991) is possibly the first comprehensive empirical effort to determine the extent of internationalization of R&D using patent data. In a series of empirical papers using the affiliation of inventors of patents to identify the location of inventive activity they show the overwhelming importance of *home-based* innovative activity for the main MNCs in the period from 1969 to 1986. The conclusions of that exercise were surprising as they clearly highlighted the importance of a \`non-globalization´ of the innovative activities of these MNCs. In particular, Patel and Pavitt (1991) suggest that in most cases these companies *"have a long way to go before their technology activities become anywhere nearly* *as globalized"*. The two scholars present only tentative explanations for the need of physical proximity. Possible explanations, as specified by Patel and Pravitt, relate to market uncertainties and characteristics of the local innovation systems, such as proximity to relevant and tacit sources of knowledge, or to facilities that incorporate and integrate multidisciplinary knowledge.

In 1996, a special issue of the IEEE Transactions on Engineering Management opens with a section dedicated to the observation that "R&D is going global"[6], and the internationalization of R&D is the topic of debate of both managers and policy makers.[7] Patel and Pavitt (1991)'s claim that *"we expect to see greater internationalization of large firms' technological activities in the future"* is echoed throughout the 1990s in subsequent studies. While this paper will not review the literature, such analysis provides ambiguous support to the claim that R&D performed at a foreign location is proving to be increasingly important for the development of core technologies. A large body of literature points to the resilience of the non-globalization argument[8] and finds little to no new evidence of globalization. Yet other scholars[9] point to different sources and suggest that indeed a growing decentralization of R&D is taking place. While there is no doubt that companies assign their foreign subsidiaries development responsibilities to adapt production to the local needs, still Kuemmerle (1999)'s argument about the coexistence of both "adaptive" and "augmentive" R&D activities is validated by subsequent empirical analysis. Home-based knowledge exploitation and augmentation do coexist and no clear trend can be isolated and generalized. My study contributes to this debate and differentiates R&D projects according to the strategic relevance of their results.

2.4. The wireless industry and the importance of standards

A priori, there seems to be little evidence to support the case for 'non globalization' of R&D and inventive activity in the wireless telecommunications industry.

During the 1980s and the 1990s, trade and regulatory liberalization of national telecommunications markets globalized the demand for telecommunications equipment, moreover technological change in the industry has had pervasive effects on R&D further upstream. One aspect of this is the ongoing convergence or fusion between various technology subfields of ICT (Information and Communication Technologies). This fusion opens up multiple entry-points for new firms and other players.

The term ICT convergence is commonly used to indicate the merging of data and telecommunications technologies, which were characterized as two separate fields until the 1980s. As a consequence, a range of new products, services, applications, markets, policy and regulatory domains are also merging (Bohlin et al., 2000). Above all, the Internet has had many important implications for telecommunications incumbents. The increasing popularity of the Internet means that mobile telecommunications applications and services must also become compatible with the TCP/IP-standards. This is also evident in a range of standardization efforts around the fringes of the core next generation standards (such as the 3G standard UMTS in Europe), examples of which include the WAP forum, GPRS and EDGE standards. (Kogut, 2004).

Standards define the interfaces of technologies that firms in the industry have to comply with in order to create new markets. Standards are typically created through different types of consortia, "clubs" or industry groups consisting of carriers, manufacturing firms, standardization bodies, and other stakeholders (Leiponen, 2005). As a result, standardization bodies have set-up various methods to support the notification and cross licensing of the intellectual property rights (IPRs) over such technologies. This to ensure that no single firm or other stakeholder be able to block the standardization process itself. On the other hand, the existence of multiple and potentially overlapping technologies and IPRs acts as an incentive for firms to strive to manage their IPRs with respect to these various notification schemes (Bekkers, 2001; Bekkers and West, 2006).

2.5. "Essential IP" and the system of patents notification

The standardization schemes delimit a subset of technologies and IPRs that are at the core of the industry in a strategic long-term sense, but that also have a relatively higher technological and economic value. The European Telecommunications Standards Institute (ETSI) defines a patent to be *essential* when "it is not possible on technical (but not commercial) grounds, taking into account normal technical practice and the state of art generally available at the time of standardisation, to make, sell lease, otherwise dispose of, repair, use, or operate equipment or methods which comply with a standard without infringing that [intellectual property]" (ETSI, 1998). Early disclosure and licensing agreements of "essential patents" are important ingredients for the smooth application of the work of the technical committee. Disclosure and licensing should eliminate roadblocks to technological development that might jeopardize the efforts of standardization partners. By avoiding a deadlock and pursuing development and adoption of a particular standard everybody will benefit, especially companies that have successfully lobbied for inclusion of their IPR in the standard.

In the case of the European standardization body ETSI, Bekkers (2001) suggests that IPR holders indeed do have strong incentives to notify their patents as essential,[10] as this is the first necessary step to lobby for single patents in the technical specifications coming out of the standardization working group. The inclusion of essential patents in an ETSI technical specification opens up various strategy avenues for the company, as well as significant licensing revenue opportunities, even under the fair and non-discriminatory agreement. The complexities of patent searches and the uncertainties related to the technological developments of the standard might suggest that ETSI members are more likely to notify and lobby for inclusion of IPRs that they are extremely familiar with and which they are convinced can be enforced and controlled further downstream in product development projects. During pre-standardization, each assignee will have to lobby and convince partners that a license to its IPRs is the most efficient way to solve a technological need, while designing around these might either be impossible or only a second-best solution. During this complex negotiation phase, it is not only the successful market adoption of a standard that is on the line but also the reputation of the IPR assignee. Thus, it seems safe to assume that these IPRs protect proprietary technologies that influence the trend of their technological activities and strategic choices in terms of commercialization. Framed in this way, it is therefore interesting to ask: to what extent are the R&D activities that lead to essential IPR homebound?

Apart from the strategic importance of essential patents, there is a debate about whether or not such patents might also be more significant in terms of their technological and economic value. A paper by Rysman and Simcoe (2006), which analyzes the notifications schemes of four major international standard setting bodies, finds that notified IPRs (patents) have a higher technological, and potentially also economic, significance than non-notified ones. The paper by Rysman and Simcoe (2006) also suggests that the data used here captures technologically and economically "more significant R&D" of the firms included.

3. Empirical Analysis

3.1. Methodology. Description of the data and the qualitative study

In this section I move on to the empirical analysis with the purpose of exploring to what degree, and how, the technological core of the wireless telecommunications industry is globalizing, and the degree to which the case for non-globalization might still have some relevance in the context of Patel and Pavitt (1991). In order to do so, the analysis presented in this paper rests on the comparative analysis of inventive location activity validated through in-person interviews with the VP for R&D and standards at the most representative companies in the industry. The comparison is here performed using patent data for the development of telecommunications standards, with a control group of similar, but ultimately less strategic patents.

With reference to the earlier discussion, the European Telecommunications Standards Institute (ETSI) represents an important standard-setting body in the European context and thus functions as a natural point of departure for data gathering. ETSI has set up a notification scheme where both members and non-members are requested to provide a written statement if their technologies and IPRs (patents) can be deemed essential to the development and inauguration of particular standards (see http://www.etsi.org/).

This empirical analysis uses patent data originally identified in the ETSI database on essential patents. These data can be accessed through online documentation containing lists of "essential patents" under various standards commissioned by ETSI. In particular, this paper considers the four largest assignees of essential ETSI patents: Ericsson, Motorola, Nokia, and Qualcomm. I take into account patents filed at the patent office in the U.S. (USPTO) during the period 1985 - 2001, and subsequently published before May 2006. Information about technology classes, date of filing and publication, affiliation of inventors, scope of international protection, keywords, backward and forward citations are also gathered. Given the arguments presented in the previous section, it seems safe to assume that the disclosed essential ETSI patents provide complete coverage over the enabling technologies discussed by the standardization committee, and that in particular, standardization partners are not concealing, or failing to disclose, essential patents.

TABLE 1: Patents Notified as Essential at ETSI by Companies

Company	Patents	Company	Patents	Company	Patents
Ericsson	241	Digital Theater Systems	6	Marconi Communications	2
Qualcomm Inc.	143	Nexus Telocation Systems	6	3COM Corporation	1
Motorola	91	Samsung	6	Ensemble	1
Nokia Corporation	78	British Telecom	5	Entrust Ltd.	1
InterDigital Technology	66	Digital Voice Systems	5	France Telecom	1
Philips Electronics	29	Mitsubishi Electric	5	Innovatron	1
Hughes Network Systems	27	Sun Microsystems	5	Intel	1
SIEMENS	19	KPN	3	IPR Licensing	1
Alcatel	18	NEC Corporation	3	Microsoft Corp.	1
AirTouch Communications	15	NTT	3	Tantivy Communications	1
TOSHIBA Corp	14	OKI Electric Industry	3	Vimatix	1
Nortel Networks Ltd.	11	Ascom Management	2	Wi-Lan	1
Lockheed Martin	7	ETRI	2		
AT&T	6	Inmarsat Ltd.	2	Total	834

Source: ETSI, data updated to April 2005.

In order to assess the case for non-globalization in the context of strategically important patents at the technological core of this industry, a control group of non-notified patents is defined according to the following steps: [11]

1. In order to define this set of patents, all the technology classes assigned to the essential patents are considered.
2. The complete portfolio of non-notified patents belonging to the same technology classes assigned during the same period to the same four companies and their subsidiaries is gathered. [12]
3. Within this portfolio, a total of 4,358 patent families, only non-notified patents that share technological keyword and backward patent citations with essential patents are considered. [13]
4. Among this subgroup of 3,501 patent families, through propensity score matching, I define a sample of 1,420 non-notified patent families that present strong similarities with

essential patents in terms of both type of patent literature cited and the technological keywords used in the abstract.[14]

With reference to the discussion above, this control group of patents can be considered less strategic, on average, from the point of view of the activities of these firms in European and global markets. This assumption requires some clarification.

Patents are not commodities, and their value distribution is often skewed as a large majority of patents assigned to companies have little to no intrinsic economic significance. The notification with ETSI makes a patent strategically relevant for the company, given that Through their notification, the usefulness and commercial value of such assets is somehow certified. By definition, control group patents have not been notified as essential to ETSI. This does not, however, exclude the possibility that at least some of the patents of them are extremely important for the company.[15] The main assumption here is merely that the strategic relevance of patents in the control group is, at the very least, more heterogeneous.

Furthermore, a comparison of inventive activities of U.S. and non-U.S. companies based on patents filed and issued by the U.S. patent office (USPTO) is biased; American companies use the USPTO as the first and main source of protection for their IP, while foreign companies might decide to file a patent in the U.S. only for a subset of their patents. The core of this analysis encompasses a comparison of patenting behavior of U.S. and European companies. It is necessary, therefore, to adopt a correction to this bias: all USPTO patents assigned to the two U.S. companies are excluded from the analysis when, within each patent family, there is no equivalent patent or application filed with at least one European patent office.[16]

In the ETSI database, 1113 USPTO patent notifications were counted. Since each patent can be notified for more than one standard commissioned by ETSI, ultimately the database contains 834 unique granted USPTO patents (see Table 1).[17] 64.4%, or 537, of these patents are assigned to the four largest assignees. As this analysis is a comparison of the inventive activities of MNCs, choosing these four companies was quite natural. Ericsson, Nokia, Motorola and Qualcomm are the largest assignees of ETSI essential patents. They are also the four most significant players in the wireless telecommunications industry in Europe and the U.S.[18]

Findings presented in the previous paragraphs require a more detailed discussion and a better understanding of the causes of the relative "homeboundedness" for essential inventive activities. The approach chosen to cater to this need was to present these research findings to top managers at the companies included in this study. During August and September 2006, interviews were conducted with VP for research, standardization, and IP management at the companies considered for this study.[19] Semi-structured discussions began by presenting the results of the inventive location analysis. Subsequently managers were presented with a set of open questions regarding the methodology, findings, relative positioning of competitors, and perspective on the industry.

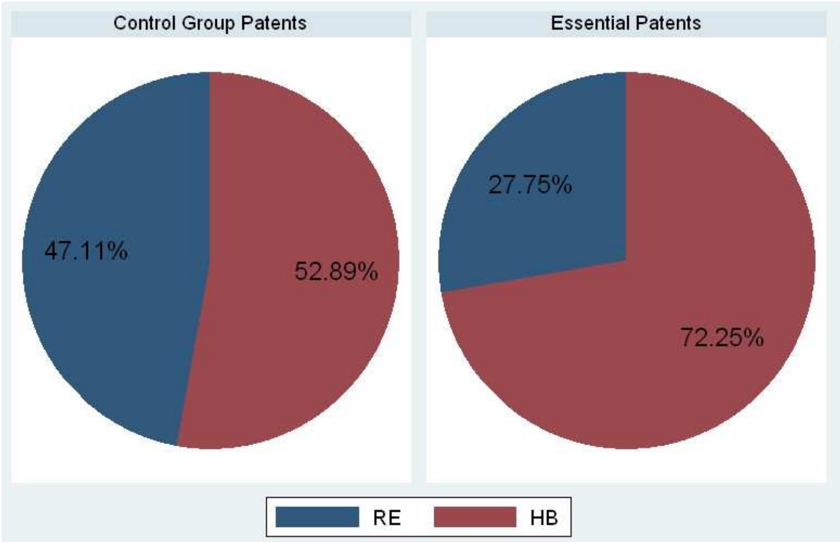
3.2. Invention location analysis

Information about the affiliation of inventors on the patent title is here used as a proxy for the location where the inventive activity leading to the filing of the patent was performed. The analysis, which resembles the approach followed in Patel and Pavitt (1991), assigns patents to these two exclusive categories.

1. HomeBased Patents (HB): patents whose inventors are all located in the HQ country (or U.S. state) of the controlling company: the U.S. for Motorola and Qualcomm (or Illinois and California respectively), Sweden for Ericsson, and Finland for Nokia.
2. Remote Patents (RE): patents which have at least one inventor located in countries (or U.S. states) other than the HQ country (or U.S. state) of the controlling company.[20]

Figure 1 shows the distribution of patents into the two categories. The share of HB essential patents is 72.25% compared to 52.89% for control group patents. Essential patents appear to be significantly more homebound than control group patents. When data is weighted using 2 years forward citations, results are similar, confirming that also forward citations to essential patents tend to be relatively more homebound than citations to control group patents.[21]

FIGURE 1: Distribution of Patents by Location of Inventive Activities (HB defined as California, Illinois, Sweden and Finland)



Pearson chi2(1) = 98.8109 Pr = 0.000

TABLE 2: Distribution of Essential and Control Groups HB/RE Patents Across Companies.

Company		Essential Patents	Control Group
All 4 Companies			
	HB	388 *(72.2%)*	751 *(52.9%)*
	RE	149 *(27.8%)*	669 *(47.1%)*
Total		**537** *(100%)*	**1420** *(100%)*
		Pearson chi2(1) = 60.0694	Pr = 0.000
Ericsson			
	HB	152 *(63.0%)*	219 *(38.9%)*
	RE	89 *(36.9%)*	343 *(61.0%)*
Total		**241** *(100%)*	**562** *(100%)*
		Pearson chi2(1) = 39.4219	Pr = 0.000
Nokia			
	HB	62 *(86.1%)*	208 *(72.0%)*
	RE	10 *(13.9%)*	81 *(28.0%)*
Total		**72** *(100%)*	**289** *(100%)*
		Pearson chi2(1) = 6.1116	Pr = 0.013
Motorola		**85**	**385**
	HB	58 *(68.2%)*	185 *(48.0%)*
	RE	27 *(31.8%)*	200 *(52.0%)*
Total		**85** *(100%)*	**385** *(100%)*
		Pearson chi2(1) = 11.3588	Pr = 0.001
Qualcomm			
	HB	116 *(83.4%)*	139 *(75.5%)*
	RE	23 *(16.6%)*	45 *(24.5%)*
Total		**139** *(100%)*	**184** *(100%)*
		Pearson chi2(1) = 2.9807	Pr = 0.084

Source: elaboration from Delphion. Patents assigned between 1985 to 2005.

Table 2 represents the distribution of HB and RE essential and control group patents across the four companies in the sample. At the company level, the Pearson Chi-Square values reported in Table 2 confirm that it is possible to reject for all companies but Qualcomm (with 0.01% significance level) the null hypotheses that the distributions of HB and RE patents are similar. For three of the four largest assignees of ETSI patents I can say that inventive activities leading to essential patents was relatively more homebound. Motorola result holds only when I consider the state level (Illinois). The Pearson Chi-Square value for homeboundedness at the country level for Motorola does not allow me to reject the null hypothesis of a difference in international distribution for essential and control group patents.[22] The case of Qualcomm is less significant for this study since most of its R&D investment during the period of observation was bound to the San Diego area, and the company had no significant R&D activities outside California.[23]

The changing distribution of patents over time shows that these four companies substantially increased the number of RE patents in the course of the late 1990s, however such a trend is less pronounced for essential patents, whose HB share remains more or less constant. Somewhat of a reverse trend can be detected for the last two years under consideration. 2000 marked the beginning of a sharp decline in the number of patents, and this decline was even sharper for RE patents as their share decreased as well.[24]

Table 3 considers exclusively the foreign locations of RE patents (defined at the country level). HB patents are excluded from this computation since, by definition, all the inventors of these patents are located either in the U.S. or in Europe.

TABLE 3: Distribution of offshore locations for RE patents

Foreign location of inventors	Control Group Patents	Essential Patents
U.S. **(for Ericsson and Nokia)**	52.0%	38.7%
E.U. **(for Motorola and Qualcomm)**	25.7%	45.2%
Canada	15.4%	6.5%
Japan	2.6%	6.5%
S.E.A.	0.7%	0.0%
R.O.W.	3.6%	3.2%
Total RE Patents	**455**	**140**

The first interesting aspect in the data is the dominant position of the United States as an affiliation of offshore inventors, both for essential and control group patents. 52% of offshore inventive activities of control group patents are performed in the U.S., while 38.7% of the patents indicated as essential show a U.S. inventor. European countries are the leading placing of foreign inventive activities for essential patents and the second for control group. Canada is also another important affiliation of inventors, and the share of Canada is higher than Japan, Asia (SEA) and the Rest of the World (ROW). Somewhat surprisingly, this latter group of countries/regions altogether represents less than 4%of all offshore patents. Hence, such emerging countries and regions are substantially absent as affiliations of inventions for ETSI standards and non-essential wireless technologies according to this analysis. Since not many inventive locations are located outside North America and Europe, and since this research looks at European and American companies only, it is possible to say that what the data describes is mostly a flow of R&D related investment from the U.S. to Europe and from Europe to the U.S.

Unfortunately the data lags behind and cannot reach definite conclusions about the R&D and inventive activities performed in the last three or four years, during which time these countries have been identified in the popular press as the largest recipients of foreign R&D investment. Nonetheless, these observations appear in line with the findings of the UNCTAD 2005 report, which describes a distribution of R&D investment still highly skewed toward these "old and incumbent" centers of innovation.

3.3. Multivariate Analysis

The scope of my multivariate analysis is to test whether, after controlling for various characteristics of individual patent titles, those that have been deemed essential through ETSI are relatively more homebound than control group patents. Through logistic regression I therefore test the hypothesis that *the odd ratio to have all inventors located in the HB country/state for patents is higher than one when patents are essential*.

Model (a), summarized in Table 4, reports the odds ratio resulting from a logisitic regression coefficient where the dependent variable takes the value of 1 if the patent is HB and 0 if the patent is RE. The model controls for characteristics of the patent such as technology class, year of application, and others. It is possible to notice that essential patents have an odds of 2.3 to 1 to be homebound. Model (a) therefore suggests that inventive activity related to essential patents tends to be relatively more homebound than that related to non-essential patents. In other words, the essentiality of a patent is a significant predictor for the domestic location of inventors. This confirms my hypothesis.[25]

TABLE 4: Logistic Regression

Dependent Variable: all inventors are located in HQ country/state (HB patents)		**Odds Ratio**	
Model:	***(a)***	***(b)***	***(c)***
An ETSI Essential patent	2.30***	2.39***	2.66***
The patent assignee is Qualcomm			5.50***
The patent assignee is Motorola			1.37**
The patent assignee is Nokia			3.98***
Essential patent x Qualcom		4.45***	0.51
Essential patent x Motorola		1.37***	1.03
Essential patent x Nokia		3.86***	0.88
Log likelihood	*-1233.90*	*-1161.32*	*-930.55*
LR chi2	*192.3 (28)*	*337.45 (31)*	*341.59 (34)*
Pseudo R2	*0.072*	*0.127*	*0.128*

Observations 1,957

Note: estimated with Stata 9.2 for Windows

The reported odds ratio are marginal effect for discrete change of the dummy variable in question from 0 to 1.

Control variables are: years dummy, technology classes, number of claims.
See the appendix for complete results.

=5% significance   *=1% significante

In Model (c), I interact firm dummies with essentiality, to better interpret the firm-specific homeboundedness of essential patenting. This model allows me to test the home-boundedness hypotheses for each individual firm.

TABLE 5: Homeboundess at the individual firm level.

Test of Hypotheses:	Is the odds ratio to be HB significantly higher than one for essential patents?					
	Odds Ratio	**Std. Err.**	**z**	**P>z**	**[95% Conf. Interval]**	
Model (a)						
Entire Group	2.30***	0.27	7.01	0.00	1.83	2.91
Model (c)						
Patent assigned to:						
Ericsson	2.66***	0.44	5.9	0.00	1.92	3.68
Qualcomm	1.35	0.41	0.99	0.32	0.74	2.44
Motorola	2.75***	0.79	3.54	0.00	1.57	4.81
Nokia	2.35**	0.88	2.3	0.022	1.13	4.88

Table 5 reports the results of the test of hypotheses, when domesticality is defined at the state level for American companies and at the country level for Nokia and Ericsson.[26] All but Qualcomm's odds ratios appear to be significantly higher than one, implying that for Ericcson, Motorola and Nokia homeboundedness is more likely in the essential patent group. In the Qualcomm case, the data does not allow me to conclude that inventors' location related to essential patents is more homebound, but this is consistent with the fact that Qualcomm up to 2001 had little R&D activity outside California.[27]

4. QUALITATIVE INSIGHTS: COMPANY POINTS OF VIEW

4.1. Validation of the patent indicator

An objective of the interviews was to *test the validity of the methodology used* in the patent analysis, and in particular the strength of the distinction between essential and non-essential IP, and the use of patents as a proxy of R&D results. The interviews confirmed both the validity of the empirical approach and the limitations of the inventive location analysis. In general, managers confirmed that the inventors' addresses on the USPTO documents are, in fact, good proxies for the countries where the R&D investments leading to those specific inventions were performed. This is direct support of the methodological discussion of Bergek and Berggren (2004), as well as the approach of Patel and Pavitt (1991), that has been partly replicated throughout this work.

In addition to the common observations above, which have also been discussed in the literature, the managers stated that confidence in the accuracy of the inventors' addresses is necessary in particular for USPTO patents, given that the U.S. system grants protection to "the first to invent" and not "the first to file". In litigation, it is often the case that assignees have to trace back laboratory reports to show the original work of inventors. A mismatch between the declared and actual location of invention can be lethal for the validity of a patent.

Nonetheless, as previously acknowledged, the lag between the time of development of inventions underlying these patents and the current events shaping R&D investment of these firms significantly limits the breadth of this study. Managers emphasized the importance of recent strategic changes that cannot yet be recorded in the analysis of the location of inventive activity. There was general consensus that in a few years the situation might be significantly different, with a lot more inventive activity taking place in peripheral and foreign locations. This was acknowledged as a general trend in the industry, even if the interviewees suggested that the homebound nature of strategic R&D of the type that we identify in this paper might not disappear.

To sum up, discussion regarding the methodology adopted for this study suggested that the inventive location analysis indeed portrays in a simple yet effective way the global distribution of R&D locations and the homebound nature of inventive activities related to essential IP. However, managers warned researchers not to draw too many conclusions about the current technology sourcing strategies at their companies.

4.2. Explanations for the homebound nature of strategic R&D

It was also important through the interviews to discuss the *various drivers of R&D internationalization* and to *understand the R&D location history and the global distribution of labor* within corporate R&D labs. Furthermore, I also asked managers to comment on *the inventive location analysis*. Finally, I discussed the various *drivers of R&D internationalization and "non globalization".* Managers were asked to explain different drivers of R&D internationalization and the relative concentration of IP assets related to the ETSI standards.

All the managers interviewed had been with their companies for a significant number of years. They were therefore in a position to discuss the latest developments, as well as provide a perspective on the past geographical distribution of the company's activities, the main motives behind certain investment decisions, and the evolution of foreign R&D labs for both "transatlantic" and decentralization in developing countries.

By and large the interviews did not highlight the cost explanation for the internationalization of R&D. Nonetheless they did confirm the importance of market demand, and the home-based exploitation and augmentation dimensions commonly discussed in the literature. Of particular interest here, however, are the reactions of the interviewed managers to the evidence for non-globalization that we find in our patent analysis. In this context they pointed to organizational inertia, rooted in the historical organization of the R&D laboratories of their companies that counterbalance the internationalization of R&D. They also refer to the maturation and learning curve dimensions related to foreign R&D subsidiaries. Further, in-house R&D is still considered important for upstream activities of a more strategic nature.

Interviews confirmed the relevance of *organizational inertia*. This phenomenon was very much relevant to explain the stickiness of core R&D projects to traditional hubs. The development of the radio technologies, based on which these ETSI wireless telecommunications standards originated, have been at the core of Ericsson and Motorola's activities. These two companies acquired and developed these technologies well before the internationalization of R&D became important, and the related knowledge appears to have accumulated locally in their home countries with a strong element of stickiness and tacitness. Based on previous research we also know that Nokia accumulated knowledge especially for the GSM standard at specific local sites in Finland, for example in the cities of Salo and Oulu (Palmberg and Martikainen, 2005). Qualcomm developed most of its expertise in California, and acquisitions in other areas (mostly in the U.S.) were targeted to expand the technological know-how into new fields.

The case of Motorola is particularly illuminating in this context. The interviewed managers at both companies were not surprised by the homebound nature of their notified essential patents. One of the managers at Motorola suggested that *"We have started to develop these technologies in Illinois and it would not make sense to source them elsewhere"*. The organizational inertia that we discussed above can therefore also be translated into a cumulative advantage for the homebound location of R&D as long as knowledge developed there is relevant for the present technological trajectory of the industry. The greatest threat to homebound R&D of the more strategic type apparently relates to technological discontinuities external to the company. *"As long as radio technologies will be used in a mobile phone, we cannot see how we can divest from our traditional R&D centers* [in Illinois]". The interviewees of all companies were convinced about this point, as well as with the assertion that it should not be taken for granted that `the next big technology' will come from the domestic R&D center.

These observations about organizational inertia and accumulated local knowledge are consistent with the vast literature on centers of excellence (see Frost et al. (2002), Birkinshaw et al. (2002)). This literature claims that foreign R&D subsidiaries will develop expertise collateral to the core competence of the firm. However, this will not lead to an internationalization of R&D projects directly related to core technologies and strategic R&D. (see references discussed in section 2.2).

The interviewees also concurred on the *maturation dimension* of foreign R&D investment as an explanation for the homebound nature of strategic R&D. In particular, foreign

R&D subsidiaries have a long *learning curve.* They can only progressively gain visibility on the overall corporate R&D organization and hence earn their autonomy for more strategic types of R&D. Foreign R&D subsidiaries might initially have been set up for home-base exploitation purposes but may subsequently mature into knowledge augmenting centers. While modularity in R&D projects connected to wireless technology allows for a fine-tuned division of labor and collaboration across different teams, the investment required to give a research team the tools necessary for their work is still considerable. Motorola managers talked about "critical mass" that has to be in place at foreign R&D subsidiaries for them to become truly operative also in terms of home-based augmentation.

The two Nordic companies added that one has to become `committed´ to a foreign location before getting anything useful out of it. Becoming committed does not only have to do with the physical investment necessary to get a foreign R&D subsidiary up and running; it also has to do with the accumulation and maturation of `soft´ and more intangible elements. Once a foreign R&D subsidiary gains sufficient credibility in the company organization it becomes a critical asset, and it is unlikely that successful subsidiaries will be divested. Until this occurs homebound R&D will thus play a predominant role for strategic projects.

4.3. Safe Nests: Centralized IP management practices as a selection bias for R&D appropriability?

So far I have considered whether and why the undertaking of more strategic R&D is homebound. In this final section I consider whether patents, which result from R&D performed at home, have a greater chance to become notified at ETSI. Since I am using patents as indicators for the organization of R&D, it could be the case that patents resulting from homebound R&D activities are also easier "to appropriate" and thus, in this particular context, have a higher probability of turning into notified essential patents in the ETSI system. To what degree does such a possible "selection bias" affect, as well as complement, our discussion in the previous section?

I define appropriability as the ability of companies to take exclusive possession and extract value from the application of technologies and other intangible assets (for a similar definition see Teece (1986) and Gans and Stern (2002)). This ability is embedded in the IP management activities of companies, on the peculiar linkages that they seek to create between exploration (R&D) activities and its commercial exploitation. It is thereby influenced by headquarters' guidelines and by the level of sophistication of an IP culture. The disclosure of inventions within the company and the filing at patent offices around the world are typically done on a decentralized basis depending on where the inventors are located. However, once patents have been filed at the patent offices, the actual strategic management of these IP assets is centralized within the company. In the context of this paper, this management concerns issues such as the notification of patents to ETSI, licensing strategies and possible litigation, as well as the ex-ante definition of patenting objectives at the corporate level.

The interviews confirmed that while IP procurement is decentralized, management and exploitation of IP assets rests within the competences of the headquarter offices. That is, inventors dispersed globally need sufficient interaction to IP managers and attorneys when filing for patents. Managers explained that inventors can get local access to decentralized patenting committees in the phase of invention disclosure, and that foreign R&D subsidiaries have to fulfill their own patenting objectives. However, managers at the four companies acknowledged that subsequent phases of IP management, such as portfolio management and exploitation of IP assets remain centralized as well as homebound. Headquarters were particularly very much involved in the selection of patents to be deemed essential for standardization.

Each of the interviewed managers agreed that not all patents are well-written and useful documents. It is quite well known that many patents are practically useless or unenforceable, as they read on claims and technologies which have already been patented, or that have no practical use. One could thus argue that R&D projects that are more closely monitored by IP experts in the home countries will also produce patents that are better written and easier to appropriate further downstream in the context of notification, licensing, and possible litigation. While the interviewee at Ericsson confirmed this idea, the interviewee at Nokia could only acknowledge a possible "IP-bias", but he could not verify this hypothesis as he had not been directly involved in IP management. The interviewees at Motorola and

Qualcomm denied the relevance of centralized IP management as a source of selection bias to explain my evidence on the case for non-globalization.

In the case of Ericsson, disclosure and patent filing take place at the site of invention. IP management is then centralized at the headquarters in Stockholm, and licensing and possible litigation are also handled at this location. However, this does not necessarily mean that R&D teams around the world are doing less strategic R&D. What this does mean is that results of R&D projects that take place abroad are more difficult to be noticed, understood in a timely fashion, and ultimately appropriated. This is best exemplified with a citation: *"by the time I know that my research team in Australia is working on a project that might have some implications for one of our standards, it is going to be too late to act on that"*. While the interviewee at Nokia could not comment on the relevance of IP management centralization, it was suggested that for standardization a close co-operation is necessary between R&D and the teams following standardization, as much support is needed in order to define technically the best solution.

Among the four companies, Ericsson has the most internationalized R&D activities and has the most remarkable difference in the foreign share between essential and control group patents. Views expressed in the course of the discussion at Ericsson did not deny the importance of path dependency in explaining why critical R&D projects are still located in Sweden. Also, great attention to IP related issues is given to research labs around the world, both in Europe and in other countries. Still, the need for some R&D projects to be closely tied to centralized IP management at the headquarters was singled out as the prevailing factor in guiding decisions to keep some of the most sensitive projects homebound.

It seems therefore that the cases of Ericsson and Nokia suggest that there is a certain degree of selection bias in my empirical analysis in so far as centralized homebound IP management provides preferential treatment of inventions with equally home-based inventors. However, this does not appear to be the case for Qualcomm and Motorola. According to the interviews this was due to a mature and global IP management system in the case of Motorola, and a concentration of most of the R&D activities around San Diego, in the case of Qualcomm. These two companies however conceded that close local coordination between R&D and IP people is a key ingredient for the exploitation of new technologies.

In light of such discussion I can assert that:

1. My quantitative analysis suggests that for three of these four companies some IP assets are more or less visible to the HQ depending on the location of R&D activity. In other words, the level of appropriability of IP assets is not uniform across the R&D network;
2. According to the views expressed by managers at Nokia and Ericsson appropriability peaks where the level of coordination between R&D and IP manager is higher, in what I here call "Safe R&D Nests".

This paper can only suggest that the discussion and empirical analysis of internationalization of R&D should take more care in considering also how IP management practices of companies affect their global dispersion of R&D. In particular, the "Safe Nests research hypothesis" would claim that home-base augmentation strategies abroad require a clearer decentralization of IP management activities in order to also secure appropriation of foreign R&D. Further research needs to establish the relevancy of this observation in other industries.

5. CONCLUSIONS: SAFE NESTS IN GLOBAL NETS

This paper suggests that the dynamics of R&D "non-globalization" brought forward some twenty years ago by Patel and Pavitt (1991) were still recognizable during a critical phase of the recent technological development of one of the most high-tech and internationalized industries. Moreover my quantitative analysis implies that the more strategic R&D and inventive activity relating to the technological core of the wireless industry is still very homebound. The observation is based on an analysis of essential patents of four significant companies (Motorola, Qualcomm, Ericsson and Nokia) in the industry set against a benchmark of non-notified control group patents. My paper brings a new contribution to the literature supporting quantitative empirical findings with a fresh interpretation.

The empirical set-up seeks to control for possible country and firm biases. Nonetheless, it hinges on the assumption that notified essential patents are strategically, and probably also technologically and economically, more significant than their non-notified counterparts in the control group. Moreover, observation only concerns the R&D and inventive activity of these firms in relation to standards commissioned by ETSI. While these are important standards in the development of the industry towards next generation wireless telecommunications technologies, these firms also hold patents of great importance to a range of other standards outside ETSI that have not been considered here. More research is needed to generalize findings beyond the setting here discussed.[28]

Despite these evident limitations, this paper presents important questions related to the organization of R&D and inventive activity in this industry worthy of exploration in subsequent research. In particular, the interviews I undertook with R&D and IP managers of all of the included firms provide complementary and novel insights on the homebound nature of strategic R&D and inventive activity in this industry. The picture presented varies for each of the four companies, and a different mix of organizational inertia, maturation, and learning curve effects, as well as IP management issue, come into play and appear to counter the drivers for R&D internationalization

Organizational inertia, maturation, and learning curve effects are well known limitations of home-augmenting R&D internationalization strategies. Indeed, the increased emphasis on knowledge creation (alleged or real) in the peripheral regions of the world led the theory to focus on various organizational modes for this phenomenon, but none of these discussions points to the international distribution of different phases of IP management. Some directions for further research might be found in Teece (2006) who suggests that not only the sources, but also the appropriability of unique sources of knowledge is the main foundation of what he calls the "special advantage" of MNCs. My hypothesis on the Safe-Nests is consistent with this view and claims that the level of appropriability is not equally distributed across the corporate R&D network. Some subsidiary centers have been more successful than others in developing the necessary expertise to exploit new technologies. One of the factors contributing to such expertise is the coordination between R&D and IP management.

This study was not set up to test the relevance of IP management coordination in foreign R&D labs. The Safe Nests argument originates to explain a potential bias in my data collection (since I consider patents as a proxy of R&D investment and inventive activities). Also, this study considers company-specific behavior during a critical juncture of the technological development of the wireless telecom industry. It is therefore quite difficult on such grounds to generalize the relevance of the Safe-Nests hypothesis, as an alternative explanation in the context of an over-reaching understanding of the homebound nature of strategic R&D and inventive activities. More case studies are needed, drawn from various other industries where a comparative methodology can be used, and evidence on the R&D and IP organization of multinationals can be gathered so that Safe-Nests can be identified and isolated.

Do inventive activities developed far from IP monitoring have a lesser chance to become visible for commercialization? Does coordination between foreign R&D teams and strategic IP management lead to higher appropriability of local R&D investment? If confirmed such claims could greatly contribute in understanding Teece's special advantage and ultimately explain cases where Patel and Pavitt's non-globalization argument still holds.

Implications for MNCs could be significant, since managers seeking to extract value from their Unsafe foreign R&D Nests might have to consider greater decentralization of IP planning and management functions.

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APPENDIX 1: Logistic regression results

MODEL (a)

Logistic regression	Number of obs	=	1957
	LR chi2(28)	=	192.30
	Prob > chi2	=	0.0000
Log likelihood = -1233.8938	Pseudo R2	=	0.0723

Dependent Variable: All inventors are located in HQ contry/state (HB patents)	Odds Ratio	Std. Err.	z	P>z	[95% Conf.	Interval]
An ETSI Essential patent	2.30464	0.2743359	7.01	0.000	1.825069	2.910228
yr1986	0.7476471	0.5781428	-0.38	0.707	.1642393	3.403426
yr1987	0.5846291	0.3710682	-0.85	0.398	.1685066	2.028355
yr1988	1.294791	0.8396458	0.4	0.690	.3632561	4.615159
yr1989	0.9665821	0.5276218	-0.06	0.950	.3315882	2.817594
yr1990	1.82404	0.9982056	1.1	0.272	.6240426	5.33156
yr1991	0.9875457	0.5306703	-0.02	0.981	.3444714	2.831139
yr1992	1.390088	0.7262578	0.63	0.528	.4992613	3.870405
yr1993	1.365777	0.7000431	0.61	0.543	.5001353	3.729683
yr1994	0.8974868	0.4488632	-0.22	0.829	.3367548	2.391897
yr1995	0.8028444	0.3956738	-0.45	0.656	.3055803	2.109296
yr1996	0.6807864	0.332236	-0.79	0.431	.2615829	1.771791
yr1997	0.8948468	0.4357815	-0.23	0.820	.344526	2.32421
yr1998	0.5688124	0.2792277	-1.15	0.250	.217329	1.488745
yr1999	0.8831202	0.440183	-0.25	0.803	.3324653	2.345812
yr2000	0.7014385	0.3659539	-0.68	0.497	.2522908	1.950194
yr2001	1.452056	0.8784527	0.62	0.538	.4436401	4.752653
USpatCl340	0.0266976	0.0203476	-4.75	0.000	.0059941	0.11891
USpatCl342	1.56718	0.5437546	1.29	0.195	.7939312	3.093535
USpatCl370	1.086676	0.2227635	0.41	0.685	.7271224	1.624024
USpatCl375	0.8982871	0.2085684	-0.46	0.644	.5698745	1.41596
USpatCl379	1.266612	0.3307502	0.91	0.365	.7592229	2.113088
USpatCl455	0.783765	0.1574874	-1.21	0.225	.5286254	1.162047
USpatCl704	2.081366	0.7931789	1.92	0.054	.9862059	4.392676
clNum10to19	0.6199883	0.0876759	-3.38	0.001	.4699054	0.818006
clNum20to29	0.5242658	0.0792531	-4.27	0.000	.3898304	0.705062
clNum30to39	0.6414054	0.124655	-2.29	0.022	.4382323	0.938774
clNum40plus	0.5751231	0.1181198	-2.69	0.007	.3845383	0.860166

MODEL (b)

Logistic regression	Number of obs	1957
	LR chi2(31)	337.45
	Prob > chi2	0.0000
Log likelihood = -1161.3201	Pseudo R2	0.1269

Dependent Variable: All inventors are located in HQ contry/state (HB patents)	Odds Ratio	Std. Err.	z	P>z	[95% Conf.	Interval]
An ETSI Essential patent	2.386207	0.2974136	6.98	0	1.869027	3.046497
The patent assignee is Qualcomm	4.45043	0.7434208	8.94	0	3.207844	6.174342
The patent assignee is Motorola	1.369632	0.1858416	2.32	0.02	1.0498	1.786903
The patent assignee is Nokia	3.857061	0.5864656	8.88	0	2.863066	5.196149
yr1986	0.6539313	0.5111059	-0.54	0.587	0.141332	3.025676
yr1987	0.549851	0.3504835	-0.94	0.348	0.157644	1.917847
yr1988	1.282272	0.8309114	0.38	0.701	0.360083	4.566234
yr1989	0.824982	0.4542387	-0.35	0.727	0.280394	2.427279
yr1990	1.736609	0.9515841	1.01	0.314	0.59331	5.083027
yr1991	0.8433733	0.4574967	-0.31	0.754	0.291257	2.442098
yr1992	1.033229	0.5440275	0.06	0.95	0.36814	2.899886
yr1993	0.9808366	0.5069688	-0.04	0.97	0.35615	2.701224
yr1994	0.5479713	0.2777701	-1.19	0.235	0.202898	1.479917
yr1995	0.5000612	0.2501424	-1.39	0.166	0.1876	1.332951
yr1996	0.4896013	0.2421519	-1.44	0.149	0.185715	1.290739
yr1997	0.6732525	0.3321683	-0.8	0.423	0.255984	1.77069
yr1998	0.4541759	0.2254513	-1.59	0.112	0.171669	1.201593
yr1999	0.6425121	0.3250432	-0.87	0.382	0.238376	1.731806
yr2000	0.4713429	0.2499497	-1.42	0.156	0.166706	1.332671
yr2001	0.5897727	0.3671422	-0.85	0.396	0.1741	1.997883
USpatCl340	0.0314806	0.0241825	-4.5	0	0.006985	0.141877
USpatCl342	1.255775	0.465369	0.61	0.539	0.607395	2.596288
USpatCl370	1.249952	0.2676106	1.04	0.297	0.821588	1.90166
USpatCl375	0.9287471	0.2246247	-0.31	0.76	0.578133	1.491994
USpatCl379	1.568597	0.4287255	1.65	0.1	0.918043	2.680155
USpatCl455	0.9717792	0.2050715	-0.14	0.892	0.642601	1.469583
USpatCl704	2.504375	0.9910212	2.32	0.02	1.153095	5.439179
clNum10to19	0.6187577	0.0910229	-3.26	0.001	0.463771	0.825539
clNum20to29	0.5859728	0.092048	-3.4	0.001	0.430691	0.79724
clNum30to39	0.7624215	0.1548459	-1.34	0.182	0.512057	1.135199
clNum40plus	0.6895595	0.1481609	-1.73	0.084	0.452564	1.050663

MODEL (c)

Logistic regression	Number of obs	=	1957
	LR chi2(34)	=	341.59
	Prob > chi2	=	0.0000
Log likelihood = -1159.2484	Pseudo R2	=	0.1284

Dependent Variable: All inventors are located in HQ contry/state (HB patents)	Odds Ratio	Std. Err.	z	P>z	[95% Conf.	Interval]
An ETSI Essential patent	2.661071	0.4410911	5.9	0	1.922932	3.682554
The patent assignee is Qualcomm	5.50423	1.112867	8.44	0	3.703372	8.180802
The patent assignee is Motorola	1.374822	0.2058311	2.13	0.033	1.025201	1.843673
The patent assignee is Nokia	3.982422	0.6603356	8.33	0	2.877448	5.511721
Essential patent x Qualcom	0.5067101	0.1737399	-1.98	0.047	0.258762	0.992243
Essential patent x Motorola	1.03365	0.3397985	0.1	0.92	0.542691	1.968768
Essential patent x Nokia	0.8840351	0.3589666	-0.3	0.761	0.398873	1.959313
yr1986	0.6234613	0.4911288	-0.6	0.549	0.133131	2.91971
yr1987	0.532915	0.3412921	-0.98	0.326	0.151889	1.869772
yr1988	1.259381	0.8187981	0.35	0.723	0.35216	4.503743
yr1989	0.8424786	0.4638997	-0.31	0.756	0.286323	2.478916
yr1990	1.754276	0.9620091	1.02	0.305	0.598848	5.13901
yr1991	0.8447601	0.4586622	-0.31	0.756	0.291457	2.44846
yr1992	1.039875	0.548382	0.07	0.941	0.36991	2.923247
yr1993	0.9969206	0.5155459	-0.01	0.995	0.361803	2.746943
yr1994	0.5659421	0.2869786	-1.12	0.262	0.209481	1.528975
yr1995	0.507904	0.2541398	-1.35	0.176	0.190487	1.354245
yr1996	0.4799802	0.2375943	-1.48	0.138	0.181916	1.266413
yr1997	0.6566643	0.3243674	-0.85	0.395	0.249392	1.729039
yr1998	0.4413862	0.2194041	-1.65	0.1	0.166611	1.169321
yr1999	0.62219	0.3153544	-0.94	0.349	0.230407	1.680161
yr2000	0.4591005	0.2439017	-1.47	0.143	0.162069	1.30052
yr2001	0.5440348	0.3403607	-0.97	0.331	0.159623	1.854206
USpatCl340	0.0308721	0.0237694	-4.52	0	0.006827	0.139615
USpatCl342	1.401568	0.5192552	0.91	0.362	0.678047	2.897135
USpatCl370	1.247578	0.2674166	1.03	0.302	0.819622	1.898985
USpatCl375	0.9310356	0.2252749	-0.3	0.768	0.57944	1.495975
USpatCl379	1.599212	0.4367353	1.72	0.086	0.936371	2.731267
USpatCl455	0.9738708	0.2056489	-0.13	0.9	0.643808	1.473149
USpatCl704	2.490372	0.9885132	2.3	0.022	1.143914	5.421694
clNum10to19	0.6166918	0.0910133	-3.28	0.001	0.461791	0.823552
clNum20to29	0.5895552	0.0928459	-3.36	0.001	0.432985	0.802741
clNum30to39	0.7761153	0.1579006	-1.25	0.213	0.520894	1.156387
clNum40plus	0.6958353	0.1495844	-1.69	0.092	0.456586	1.06045

Appendix 2: Interviews conducted

Date	Name of the Interviewee	Company	Role in the company
August, 08	Phil Gilchrist	Motorola	VP 3GSM Platform Reference Design Engineering Mobile Device Business
September, 01	Miguel Pellon	Motorola	Vice President, Technology - Standards
September, 16	Nhils Forslund	Ericsson	assistant to the VP for Standards and Corporate Manager for IP strategy
September, 18	Timo Ali Vehmas	Nokia	VP Standards and industry relations
November, 30	Ed Tiedemann	Qualcomm	VP Standards

APPENDIX 3: Structure of the Interviews

Conversations with managers were divided into two parts. During the first half of the interview managers were presented with the results of the study. Subsequently, discussion was guided through a set of open questions.

Questions were presented according to the following sequence:

Open Question 1

- How "essential" are the essential patents?
  – More significant technologies?
  – More strategic R&D?
  – Lying the closest to the changing technological core of the industry?
- How "non essential" are the non essential patents?
  – Less significant technologies?
  – Quantity matters for strategy?
  (Large portfolio of non essential patents)
  – Back up technologies? Different technological paradigms?

Open Question 2

- Why are Essential Patents Homebound?
  – National Location Advantages?
  (absorptive capability, ties with local innovation system and knowledge centers)
  – Organizational Inertia/Path Dependency?
  Foreign R&D investment to serve foreign markets, different sources of specialization
  – IP-Management and Control of Essential Assets

Open Question 3

- What can we say about the internationalization of R&D if we look at patents?
  – Not all R&D is patented/patentable
  – Different emphasis and incentives to patenting across the organization? (in the home country and abroad?)
- Nokia's distribution of R&D Labs?
  – (location, size, type of activities, relation to essential patenting, relation with local demand, ties with the local innovation system)

Open Question 4

- How and why does Nokia's Model differ?
  – The data seems to suggest an interesting profile for Nokia (homebound & closed innovation for essential patents, and open and global for the wireless patents)
- What about the other three firms?
  – Ericsson, very similar to Nokia
  – Motorola, closed! Homebound for the essential, and Global for the non-essential
  – Qualcomm, open but homebound

Open Question 5

- Upstream Standard Setting Vs
Downstream Technology Integration?
  - Is R&D internationalization and open innovation the main mode for technology integration?
  - When do R&D alliances enter the picture?
    - Essential patenting?
    - Standard setting?
    - Technology integration?
    - Commercialization?
  - What are the IP Management challenges?

Open Question 6

- What's Next?
  - The rise of China and India?
  - The demise of the Nordic countries?
    - Advanced Users?
    - Killer applications (IP Telephony,…)?
    - The role of Sweden as a location for R&D?
  - Next Generation Standards?
    - Within 3G competition (TD-SCDMA, WCDMA, CDMA2000)?
    - Beyond 3G/4G?
    - The Internet?

Endnotes

[1] The already cited UNCTAD (2005) report offers a comprehensive overview of international trade and investment.

[2] A classic starting point here is Baldwin and Clark (2000) Brusoni et al. (2001) apply the concepts of modularization to the organization and extension of R&D projects.

[3] Even though the empirical analysis presented in the next sections does not directly address the cost advantage explanation for the internationalization of R&D, it is important to acknowledge its relevance. Organizational challenges, related to the offshoring of the most labor-intensive phases of R&D to low-cost countries are not easy to overcome. Expertise of dispersed teams, as well as the architectural complexities of each single product or component, will ultimately determine whether or not a project requires geographical proximity For a detailed study of product development and modularization of tasks across dispersed research teams in semiconductors, see Schofield and Gregory (2004). Global players might decide to relocate the most labor-intensive phases of their R&D effort to regions that are desirable, not for the size or growth rate of their market, nor for other cutting edge R&D activities located in the area, but simply because of the availability of qualified and cheap technical expertise. The development of ICT infrastructures is now making available qualified and cheap human capital located in rapidly developing countries (most notably India, South East Asia, China) and transitional economies (Eastern Europe). This has, in turn, already led to the delocalization of low-end support service functions. It is quite likely that firms that have already gone through a delocalization of back-office operations will now look at the same areas as possible locations to move some parts of their R&D operations. Being the first to open up a subsidiary in a foreign country is a risky venture; closures and downsizing of FDIs are a very common phenomenon. When a company gains understanding of the local institutions and business climate it is likely to consider "upgrading" its investment in that territory before plunging into a grassroots investment in a new region (examples of upgrading have been studied in particular in the software industry: see O'Riain, 1997 for a study of Ireland; Dossani and Kenney, 2003 for back office operations in India).

[4] For a more complete review of the literature on the organizational dimension of foreign R&D activities, see Werner (2002) and Zanfei and Solvell (2000).

[5] Numerous studies challenge the argument that "maturation" is working only one way, and that R&D centers originally adapting R&D to foreign markets then become centers of excellence and learning centers of new technologies. According to many studies, demand adaptation remains the main driver for FDI in R&D. See here Dunning and Narula (1995); Anand and Kogut (1997); Hakanson and Nobel (1993); Hagedoorn and Narula (1996); Guellec and van Pottelsberghe de la Potterie (2001); Athreye and Keeble (2000); Gertler et al. (2000); Yeung (1999); Zanfei (2000); Le Bas and Sierra (2002); von Zedtwitz and Gassmann, 2002).

[6] IEEE Transactions on Engineering Management (1996), Vol.43, 1.

[7] A series of OECD reports (see for example: OECD, 1993) started to infer the policy implication of a global interconnection of technology development activities and the need of countries to create the necessary conditions to attract this form of investment.

[8] See here among others: Patel (1996), Duysters (1996), Kleinknecht and ter Wengel (1998), Patel and Vega (1999), Meyer-Krahmer and Reger (1999), Rama (1999), Asakawa (2001), Belderbos (2001), Kumar, 2001, Mowery (2001), Edler et al. (2002), Mendez, 2002, Bergek and Berggren (2004), Macher et al. (2007).

[9] See here: Pearce and Singh (1992), Cantwell (1992 and 1995), Schott (1994), Dunning (1995), Shan and Song (1997), Guellec and van Pottelsberghe de la Potterie (2001), Le Bas and Sierra (2002), and Cesaroni et al. (2004). For a recent review of R&D globalization in various industries see Macher and Mowery (2008).

[10] The alternative here is to "act strategically", timing the disclosure of essential IP in order to create "lock-in" situations for the partners. Both partners of the standardization committee and third parties, which hold supposedly essential IPRs, might fail or voluntarily conceal the potential infringement by the standards of technologies that they have already patented or that they are currently developing and are going to be covered by patents. This type of behaviour attempts to maximize future licensing revenue but threatens the future success of the standard. For a variety of reasons not discussed here (See Bekkers 2002), in the case of ETSI wireless standards, late disclosure or concealment of potentially essential patent did not constitute a problem for the commercial application of standards and we think that it should not constitute a troublesome bias for the empirical analysis discussed in section 3.

[11] Results discussed in the empirical section are confirmed using various control group sampling and selection of non-notified patents on the basis of technological similarity to essential patents. Given the diversified activities of some of the companies represented in this study I choose to compare here results using the most restrictive sampling, obtained according to the approach here described. The goal of such sampling is to select non-notified patents that protect technology which is similar to that of essential patents. In other words, when considering exclusevely the characteristics of the technologies protected, essential and control group patents should have the same probability to be deemed essential.

[12] In order to gather the most complete set of patents filed by the company and its controlled subsidiaries, original search strings are used combining the parent company with its fully owned subsidiaries (data gathered through Mergent Online and Who Owns Whom). Possible variations of names for the same companies were also considered. Patent data was gathered through Thomson's Dialog search service. Dialog constantly checks patents for misspellings and incorrect information.

[13] Keyword extraction was performed using the Vantage Point software developed by Search Technology Inc.

[14]Out of the 4,358 non-notified patents belonging to at least one of the technology classes of essential patents, 3.501 patent families do either (a) cite at least one patent cited by at least one essential patent, or (b) include in their abstract at least one of the technological keywords extracted in at least one essential patent. Out of this subset, through propensity score matching I select a control group of 1,420 identifying the closest neighbourghs to essential patents on the basis of technological keywords used and backward citations. Propensity score matching was performed using the psmatch2 module in STATA described in Leuven and Sianesi (2003)

[15] No information has been gathered about the current use of these patents, and it is not possible to convincingly predict their future use. Even if I assume that these patents will not be deemed essential for ETSI standards, some of them might indeed protect critical aspects of a commercialized product, be relevant for other standards, or become the objects of profitable licensing contracts. As note 18 explains, the assumption of less strategic relevance of control group patents is confirmed with forward patent citation analysis.

[16] The Delphion Patent Family database is used for this procedure. For the sake of clarity, throughout the rest of the paper the two sets of patents are referred to as the "essential patents" and the "control group patents," stressing again that all the ensuing tables and figures contain data collected at the level of patent families and that "non internationally protected" patents assigned to U.S. companies are excluded.

[17] All USPTO essential patents assigned to U.S. companies have at least one European equivalent in the patent family. This means, *de facto,* that the "international protection" correction just discussed applies exclusively to the control group. This is not surprising, given the commercial relevance of these patents on the European market.

[18] I also consider forward patent citations to weight the importance of single patents. Forward patent citations, defined as the number of patents citing a specific patent, are used as a proxy for the usefulness and technological significance of each individual patent. For each patent, all non-self forward patent citations received in the two years after each patent was granted are considered. The discussion of a different strategic value of essential and control group patents finds some evidence in the patent citation analysis. Essential patents have a statistically significant higher average forward citation rate (4.2 citations per patent) than that of the control group (2.82 citation for patents). Essential patents, by definition, are patents whose commercial application and usefulness have been somehow certified through their notification. They are therefore more likely to get cited as relevant prior art by subsequent and related patents, than patents in the same technological classes that are not identified as essential ones. The citation rate of patents by Qualcomm is the highest and stands out. Qualcomm essential patents received on average 6.21 citations, and its non essential patents 4.1. This holds for both essential and control group patents, even when controlling for the age of patents. Qualitative investigation with industry experts suggests that Qualcomm is developing technologies of a more generic (or enabling) nature and, as a result, it plays the double role of competitor and technology provider (in particular for the CDMA and 3rd generation networks). Generic technologies are likely to receive more citations than more application-specific patents, since their range of application is much broader.

[19] See Appendix for a complete list of the interviews conducted and questions made. Interviews were not recorded, but notes from the interviews were sent back to the interviewees for comments and amendments. Interviews lasted between one and two hours, one was conducted over the phone and the others in person. It was possible to get interviews with top managers at these companies thanks to the mediation of faculty and researchers taking part to a joint project at the University of California, Berkeley and ETLA the Research Institute of the Finnish Economy.

[20] This analysis considers data at the country level for the two European companies and at the state level for the two U.S. corporations. I chose this approach to clearly identify the location of the main R&D hub, for each of these four companies. Motorola and Qualcomm display a significant concentration of their R&D activities around the Chicago and San Diego area respectively; in the proximities to their global headquarters. As for the European companies, in spite of the presence of various regional labs scattered in Finland and Sweden, much of the homebound R&D is performed in the main labs outside Helsinki (Nokia) and Stockholm (Ericsson). Other reasons, such as linguistic and cultural similarities, mobility of the labor market, enforcement of the IPR system might have suggested a different level of analysis, especially for the U.S. companies. In the remaining of the paper I will therefore consider how results vary when considering U.S. country level data.

[21] This is not surprising given that on average essential patents tend to receive more citations than control group patents. Out of the total portfolio of 2 years forward citations to essential patents, 75.27% cite an HB patent, whereas out of the same portfolio of citations which cite control group patents, 57.05% cite HB patents. For both patent count and citations, the Pearson Chi-Square values confirm that it is possible to reject (with 0.01% significance level) the null hypotheses that the homeboundness of inventive activity locations is similar for essential and control group patents. This holds true both when I use county-level, and state-level specifications of homeboundness.

[22] In the course of the interviews at Motorola (discussed in the next section), managers focused on the relevance and concentration in Illinois of the R&D activities on radio technologies, rather than on the dimension of "homeboundness". Traditionally, I

was told, Motorola developed such competence in its main R&D laboratories. While significant investments took place around the U.S. and in other foreign countries, it was still a natural transition, for the main working group specializing on radio technologies, to take the lead on the development of GSM and other ETSI standards.

[23] Qualcomm's share of essential HB patents (83.4%) is higher than in the control group (75.5%), however the small number of observation of RE patents does not allow me to suggest that such difference is statistically significant.

[24] The sharp decline in the last two years might have been biased by a database tailing effect. Patents are grouped by application date, and for some of the latest years patents might have been still under review at the USPTO by the time the empirical analysis was conducted. In spite of this bias, it is well known that after the euphoria of the late 1990s and the strong emphasis on patenting, some rationalization of R&D budgets took place in the industry, and this is likely to have impacted domestic and foreign R&D activities differently.

[25] Results for Model (a) hold also when I use county-level specification of homeboundness for the two U.S. companies.

[26] At the country level the coefficients for the two American companies in the samples appear not to be significant.

[27] As I have already discussed, nearly all of Qualcomm's R&D was homebound and thus the non-significance of the coefficient is driven by the lack of the comparison group.

[28] I would also like to acknowledge here a comment made by an anonymous reviewer, who suggested that an interesting alternative unit of observation could have been inventors or inventive teams rather than individual patents. In this study two individual patents authored by the same inventor count as two distinct observations. Considering the homeboundness of inventive teams rather than invention, and in particular the location of the most prolific inventive teams could be an interesting research question for subsequent works.